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AN EXPERIMENTAL STUDY ON THE AUTOMOTIVE PRODUCTION LINE USING ASSEMBLY LINE BALANCING TECHNIQUES

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ABSTRACT

The main aim of an assembly line is to group the different facilities and workers in an efficient manner in order to obtain effective utilization of man power and machine. This calls for uniform rate of production as well as decrease in the work in process inventory. Hence, this paper attempts to achieve these in an assembly line of an automotive manufacturing unit using three different techniques such as Largest candidate rule (LCR), Kilbridge and wester column method (KWC) and Rank positional weighted method (RPW). All the three methods show better efficiency and a comparison is also drawn amongst the three to determine the best suited technique pertaining to the current research work.

Key words: Largest candidate rule, Rank positional weight, kilbridge and wester column method, assembly line balancing.

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1. INTRODUCTION

Assembly line balancing consists of a series of work stations that comprises of work elements. A set of work element having tasks which have a defined cycle time or operating time with a set of interrelated activities in a certain order. Each work element possesses a task time which is a standard time to complete the elemental task. The collective time of all the workstations is the total work content that determines the total time for the assembly. Assembly line balancing is mainly done for the effective utilization of machine and to achieve less congestion within the production system. The three suitable techniques of assembly line balancing i.e. largest candidate rule, kilbridge and wester column method and rank positional weighted method are applied here to determine the best results pertaining to the assembly line which will eventually decrease the idle time and material handling.

2. LITERATURE REVIEW

Assembly planning and line balancing was integrated [1] to incorporate decisions on process planning. the system methodology was first explained along with the drawing of the product. The precedence diagram is drawn that gives us visual explanation of the assembly line. A heuristic procedure for assigning the tasks in the assembly line was performed using kilbridge and wester column method. The aim was to minimize the balance delay and providing smooth postural load in-between the workstations [2]. A detailed study [3] was presented regarding the balancing in a production system. The problems of assembly lines are classified as simple and general model assembly line balancing problems. Mathematical model, heuristic procedure and stochastic algorithm are proposed for optimizing the balancing problems. Largest candidate rule and kilbridge and wester column method were explained in detail using flow chart. In order to not violate the cycle time and precedence constraints, largest candidate rule is determined to assign tasks to the workstation and maintain smooth and continuous flow [4]. A comparison was done between LCR and KWC to a better line efficiency amongst the two on a refrigeration plant. These methods showed huge improvements when compared with the existing line that helped distribute the task evenly so that the idle time of both the machines and men are decreased [5]. A manual assembly line balancing was done by all the three methods of LCR, KWC and RPW and was found that RPW provided the best results with a very high line efficiency as well as labour efficiency [6]. Another researcher also computed the assembly line balancing using all the three methods and tabulated the results pertaining to idle time, line efficiency and smoothness index [7]. Coming to the practical scenario, when applying these methods, they show drastic improvement. Researchers [8] have applied Largest candidate rule in the garment industry and the assembly line efficiency have increased up to 26%. And also, the productivity increased. Thus, this paves way for its application in a real time huge manufacturing set ups. LCR can also be studied on computational experiments that will help to make the software more user friendly and interactive [9]. Different balancing methods were evaluated with the help of operation time. Remaining time is computed at each workstation and then analyzed using rank positional weight method (RPW) [11]. Researchers also found that RPW is a method that minimizes the workstations thereby minimizing the balance delay and ultimately improving the line efficiency. slack time is reduced task is completed in a shorter time [12]. A multi-product assembly line balancing problem [13] was investigated using the method of RPW. The methodology provides a clear scenario of the work done and an expert system is proposed. The bottlenecks of an engine assembly were decreased by RPW method thereby increasing the production by25% [14]. Other researches [15] have used other methods such as genetic algorithm to solve the assembly line balancing problems.

3. CASE STUDY

The Autoline industry manufactures sheet metal components, sub-welding assemblies and assemblies for the automobile industry. The present research work focusses on the assembly line balancing of the high deck body.

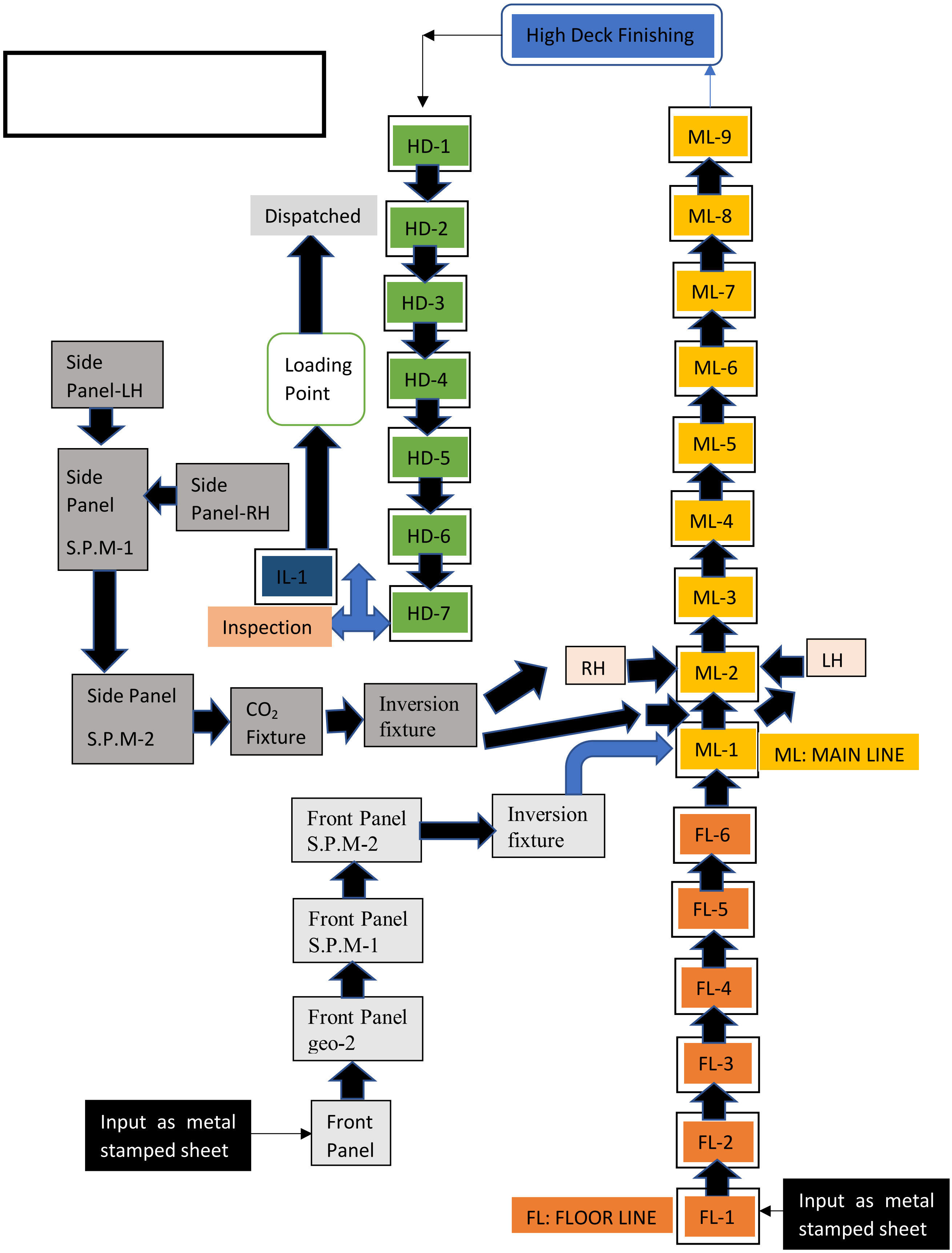

Figure 1 Assembly line plant Layout

Data recorded in observing the ace high deck body assembly line.

- Total maximum production time = 12 hours/day = 720 min
- Breaks and maintenance/cleaning time = 60 + 40 min = 100 min
- Production time = 620 min.
- Average no. of workers = 70-72/day.
- Targeted body = 50/day.
- Idle time= 40 min /day

The assembly line consists of five stages that consists of floor line, main line, finishing line, front panel and side panel.

Table 1 observed time for different workstation

Workstation	Observed Time
Floor line	16.19
Front Panel	8.17
Side Panel	13.02
Main line	28.29
Finishing line	24.41
Total	90.08 min

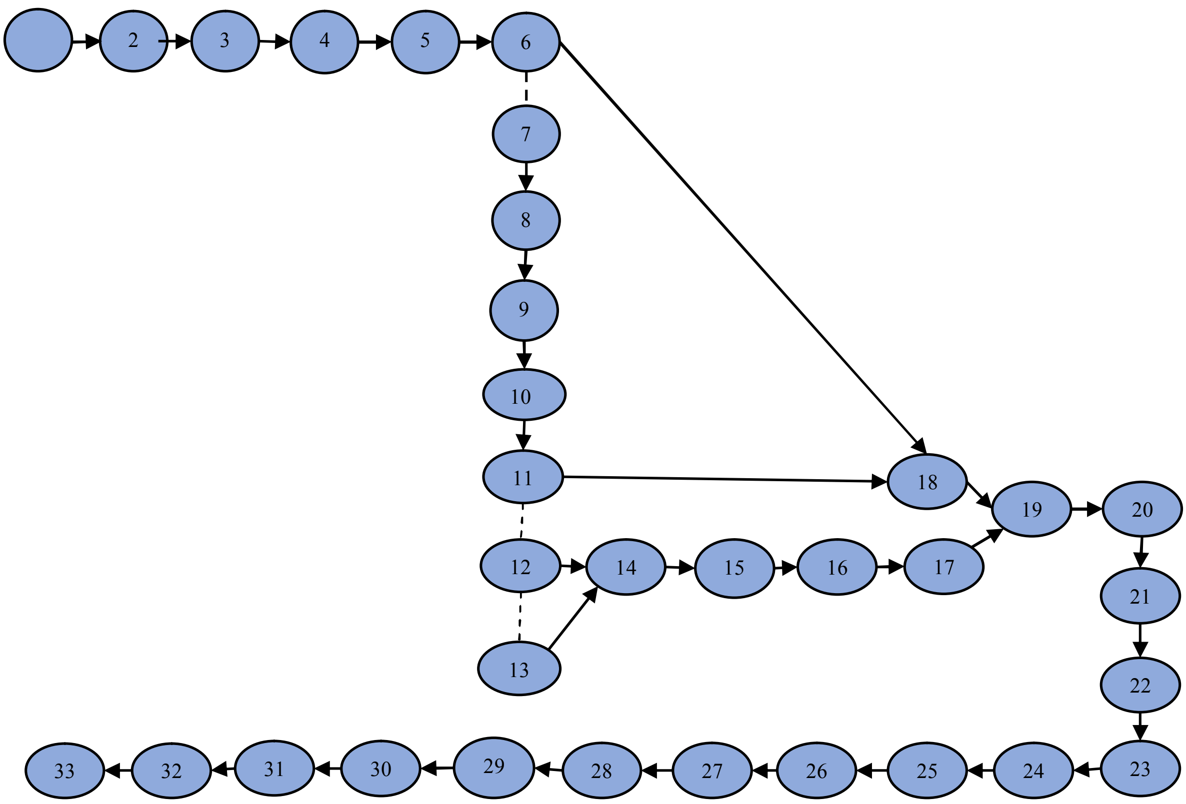

Figure 2 Precedence diagram

Table 2 Line data

Components	Elements	Cycle time (min)	Precedence
Floor line-1	1	2.46	---
Floor line-2	2	2.58	1
Floor line-3	3	3.15	2
Floor line-4	4	2.37	3
Floor line-5	5	3.20	4
Floor line-6	6	2.03	5
Front Panel	7	1.37	---
Front panel geo	8	3.08	7
Spot permanent maching-1	9	2.50	8
Spot permanent maching-2	10	1.11	9
Inversion fixture-1	11	0.11	10
Side Panel LH	12	2.51	---
Side Panel RH	13	2.24	---
Spot permanent maching-1	14	1.15	12,13
Spot permanent maching-2	15	1.10	14
Spot permanent fixture	16	2.36	15
Inversion fixture-2	17	3.26	16
Main line-1	18	2.39	6,11
Main line-2	19	4.13	17,18
Main line-3	20	3.18	19
Main line-4	21	4	20
Main line-5	22	3.47	21
Main line-6	23	3.32	22
Main line-7	24	3.1	23
Main line-8	25	2.37	24
Main line-9	26	2.33	25
High deck-1	27	2.39	26
High deck-2	28	2.30	27
High deck-3	29	2.38	28
High deck-4	30	2.10	29
High deck-5	31	3.24	30
High deck-6	32	2.53	31
High deck-7	33	9.47	32

4. RESEARCH METHODOLOGY

The methodologies used in this research work consists of assembly balancing techniques such as Largest candidate rule, rank positional weighted method and Kilbridge and wester column method. The parameters of assembly line balancing are as follows:

- Cycle time = (Total available production time)/ Total No. of units to be produced
- Min no. of workstations required (theoretical) = Total Work Content/Cycle time
- Balance delay = [(No of workstations*Cycle Time – Total Work Content)/ (No of workstations*Cycle Time)] x 100
- Line Efficiency = (100 – Balance Delay) %
- Line Smoothness Index $SI = \sqrt{\sum_{j=1}^{k} (S_{\max} - S_j)^2}$

4.1. Largest Candidate Rule

The steps involved are: -

- List all the elements in the decreasing order of their elemental task time
- To assign an element in a work station to start from the beginning of list moving downward searching first feasible element which can be placed in a workstation? A feasible element is one that satisfy the precedence requirement and when that element is placed in a workstation, the total time of work station should not exceed the cycle time
- Strike off the element which is assigned to a work station so that it cannot be considered again.
- Continuing in the similar manner until all the elements are assigned to different workstation.

Table 3 Sorted data for LCR

Elements	Cycle time (min)	Precedence
33	9.47	32
19	4.13	17,18
21	4	20
22	3.47	21
23	3.32	22
17	3.26	16
31	3.24	30
5	3.2	4
20	3.18	19
3	3.15	2
24	3.1	23
8	3.08	7
2	2.58	1
32	2.53	31
12	2.51	---
9	2.5	8
1	2.46	---
18	2.39	6,11
27	2.39	26
29	2.38	28
4	2.37	3
25	2.37	24
16	2.36	15
26	2.33	25
28	2.3	27
13	2.24	---
30	2.1	29
6	2.03	5
7	1.37	---
14	1.15	12,13
10	1.11	9
15	1.1	14
11	0.11	10

Table 4 Largest candidate rule method

Workstations	Elements	Cycle Time (min)	Total Work Content	Ideal Time
I	12 1 2 3 4 5	2.51 2.46 2.58 3.15 2.37 3.2	16.27	1.74
II	13 6 7 8 9 14 10 15 11	2.24 2.03 1.37 3.08 2.5 1.15 1.11 1.1 1.11	15.69	2.32
III	18 16 17 19 20	2.39 2.36 3.26 4.13 3.18	15.32	2.69
IV	21 22 23 24 25	4 3.47 3.32 3.1 2.37	16..26	1.75
V	26 27 28 29 30 31 32	2.33 2.39 2.3 2.38 2.1 3.24 2.53	17.27	0.74
VI	33	9.47	9.47	8.54
Total			90.28 min	17.78 min

- Balance delay = $\frac{(6 \times 18.018) - 90.28}{6 \times 18.018} \times 100 = 16.49\ \%$
- Line efficiency = 100 – 16.49
  = 83.51 %
- Smoothness index $= \sqrt{[(17.27-16.27)^2+(17.27-15.69)^2+(17.27-15.32)^2+(17.27-16.26)^2+(17.27-17.27)^2+(17.27-9.47)^2]} = 8.31$

4.2. Kilbridge and Wester Column Method

The elements in this method are selected for assignment to stations on the basis of their position in the precedence diagram. Therefore, all the elements were arranged in the form of columns in the diagram which in turn is organized into a list according to their column, with the elements in the first column is taken first. The highest value of each column is placed first.

Subsequently, repeating the previous steps for as many additional stations as possible until all elements have been assigned as shown in the precedence diagram [7].

Table 5 KWC for Assembly line

Elements	Cycle time(min)	Column	Precedence	Workstation	Total work content	Ideal time
1	2.46	A	---			
33	9.47	B	32			
2	2.58	B	1			
3	3.15	C	2	I	17.66	0.35
32	2.53	C	31			
31	3.24	D	30			
4	2.37	D	3			
5	3.20	E	4			
30	2.10	E	29			
8	3.08	F	7	II	16.52	1.49
12	2.51	F	---			
9	2.50	F	8			
29	2.38	F	28			
13	2.24	F	---			
6	2.03	F	5			
7	1.37	F	---			
11	1.11	F	10			
12	0.11	F	---			
28	2.30	G	27			
14	1.15	G	12,13	III	17.7	0.318
27	2.39	H	26			
15	1.10	H	14			
16	2.36	I	15			
26	2.33	I	25			
17	3.26	J	16			
18	2.39	J	6,11			
25	2.37	J	24	IV	16.2	1.81
19	4.13	K	17,18			
24	3.1	K	23			
21	4	L	20			
22	3.47	L	21	V	14.7	3.31
23	3.32	L	22			
20	3.18	L	19	IV	6.5	11.51
Total					89.28 min	18.78 min

- Balance delay $= \dfrac{(6 \times 18.018) - 89.28}{6 \times 18.018} \times 100 = 17.41\ \%$

- Line efficiency = 100 – 17.41
  = 82.59%

- Smoothness index $= \sqrt{[(17.7-17.66)^2 + (17.7-16.52)^2+(17.7-17.7)^2+(17.7-16.2)^2+(17.7-14.7)^2+(17.7-6.5)^2]}$
  = 11.61

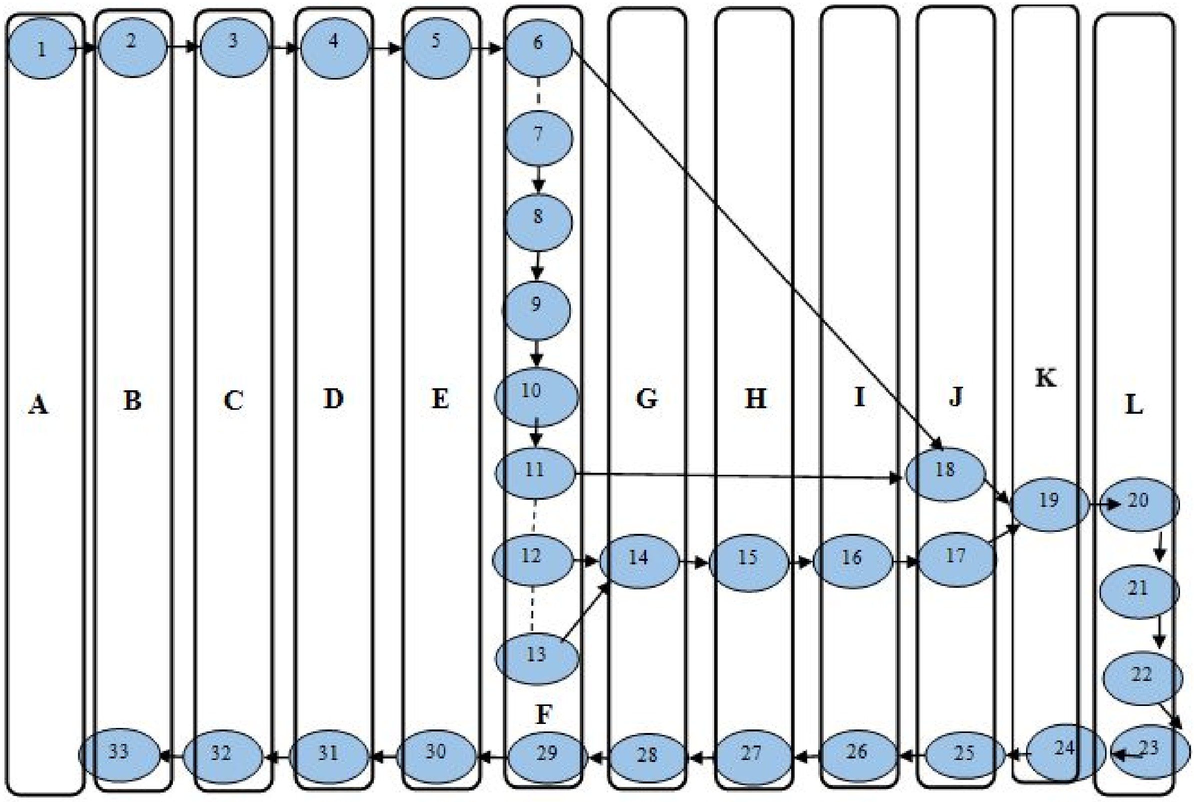

Figure 3 Works elements arranged by KWM

4.3. Rank Position Wighted Method

The elements are arranged in a decreasing order of their positional weight. The positional weight of an element corresponds to the time of the longest path from the beginning of the element to the reminder of the network. It can be said as a combination of largest candidate rule and kilbridge and western method [10].

Table 6 Rank Positional weight for assembly line

Components	Elements	Cycle time (min)	Precedence	Positional Weight
Floor line-1	1	2.46	---	72.62
Floor line-2	2	2.58	1	70.16
Floor line-3	3	3.15	2	67.58
Floor line-4	4	2.37	3	64.43
Floor line-5	5	3.2	4	62.06
Floor line-6	6	2.03	5	58.86
Front Panel	7	1.37	---	65
Front panel geo	8	3.08	7	63.63
Spot permanent maching-1	9	2.5	8	60.37
Spot permanent maching-2	10	1.11	9	58.05
Inversion fixture-1	11	0.11	10	56.94
Side Panel LH	12	2.51	---	64.82
Side Panel RH	13	2.24	---	64.55
Spot permanent maching-1	14	1.15	12,13	62.31
Spot permanent maching-2	15	1.1	14	61.16
Spot permanent fixture	16	2.36	15	60.06

Inversion fixture-2	17	3.26	16	57.7
Main line-1	18	2.39	6,11	56.83
Main line-2	19	4.13	17,18	54.44
Main line-3	20	3.18	19	46.18
Main line-4	21	4	20	43
Main line-5	22	3.47	21	39
Main line-6	23	3.32	22	35.53
Main line-7	24	3.1	23	32.11
Main line-8	25	2.37	24	29.11
Main line-9	26	2.33	25	26.74
High deck-1	27	2.39	26	24.41
High deck-2	28	2.3	27	22.02
High deck-3	29	2.38	28	19.72
High deck-4	30	2.1	29	17.34
High deck-5	31	3.24	30	15.24
High deck-6	32	2.53	31	12
High deck-7	33	9.47	32	9.47

Table 7 Line Balancing Results from RPW

Workstation	Elements	Positional Weight	Cycle time (min)	Total work content	Ideal time
I	1	72.62	2.46	16.68	1.33
	2	70.06	2.58		
	3	67.58	3.15		
	7	65	1.37		
	12	64.82	2.51		
	13	64.55	2.24		
	4	64.43	2.37		
II	8	63.63	3.08	16.53	1.48
	14	62.31	1.15		
	5	62.06	3.2		
	15	61.16	1.1		
	9	60.37	2.5		
	16	60.06	2.36		
	6	58.86	2.03		
	10	58.05	1.11		
III	17	57.7	3.26	17.07	0.94
	11	56.94	0.11		
	18	56.83	2.39		
	19	54.44	4.13		
	20	46.18	3.18		
	21	43	4		
IV	22	39	3.47	16.98	1.03
	23	35.53	3.32		
	24	32.11	3.1		
	25	29.11	2.37		
	26	26.74	2.33		
	27	24.14	2.39		
V	29	19.72	2.38	12.55	5.46
	30	17034	2.1		
	31	15.24	3.24		
	32	12	2.53		
VI	33	9.47	9.47	9.47	8.54
Total				89.28 min	min

- Balance delay = $\frac{(6 \times 18.018) - 89.28}{6 \times 18.018} \times 100 = 17.41\ \%$
- Line efficiency = 100 – 17.41
  = 82.59%
- Smoothness index= $\sqrt{[(17.07-16.68)^2 + (17.07-16.53)^2+(17.07-17.07)^2+(17.07-16.98)^2+(17.07-12.55)^2+(17.07-9.47)^2]}$
  = 8.8

5. CONCLUSION

The graph shows the comparison of various parameters of the three assembly line balancing techniques. It can be seen that the smoothness index of largest candidate rule and Rank positional weighted method are less than kilbridge and wester column method. This means that the smoothness of the production flow will not be good according to KWC method. LCR shows the best line efficiency when compared to RPW and KWC. Also, LCR has the least idle time of all. Thus, while looking at the overall performance, Largest Candidate rule of assembly line balancing method is the best technique that could be followed for this case study.

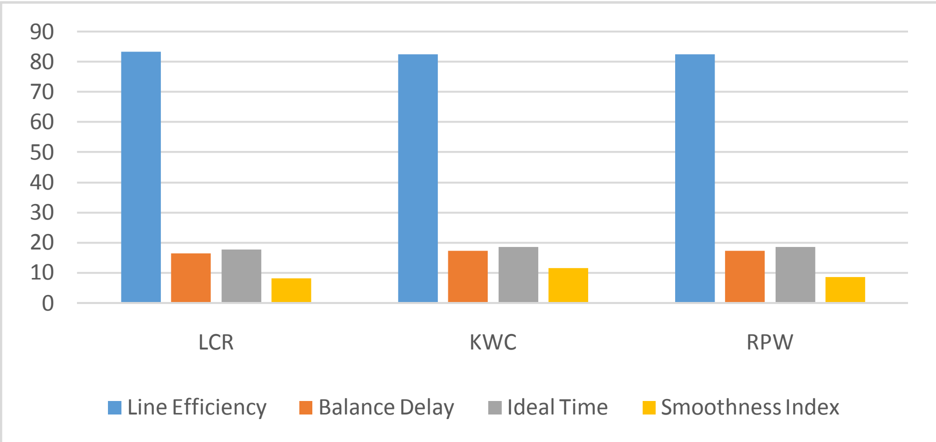

Figure 4 Comparison of parameters for all the techniques

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